November 1997 Highlights of the Pulsed Power Inertial Confinement Fusion Program

anode plate
wire arrays

Nested wire arrays used on shot 140. The complex arrays motivated development of a new wire-array fixture to make wiring the arrays easier.

Z pinch and ion diode talks, including four invited talks by Sandians, were given at the APS Division of Plasma Physics meeting in Pittsburgh. Of the nine shots this month, two were LANL shots to evaluate weapons physics concepts, five were to measure the vacuum hohlraum temperature with a new soft x-ray spectrometer, and two were to evaluate radiation transport from a tapered central cylinder inside a wire array to an on-axis, foam-filled secondary hohlraum. On November 17, Z was shut down for two weeks of maintenance and refurbishment.

on-axis secondary
anode plate
pinch region

diagnostic hole
tapered, foam-filled cylinder
Hardware inside wire array on shot 156.

Bremsstrahlung image on shot 157. Hardware is as shown in photo at right, except tapered foam cylinder for this shot was not covered with 2 μm gold.

The second generation of a time-resolved soft x-ray spectrometer, proposed as a National Ignition Facility (NIF) Phase-I diagnostic and first used on Saturn, was fielded on Z for the first time during the vacuum hohlraum experiments. This instrument measured a hohlraum temperature of 140 ± 10 eV, corrected for hole closure and viewing angle, on two vacuum hohlraum shots with a 2-mm-wide gap between the wire array and the hohlraum wall.

A four-shot series in October with nested wire arrays (top figure) were done in collaboration with DGA, France, based on suggestions from NRL, Sandia, LLNL, and Tomsk. The outer to inner array mass was varied while keeping the implosion time constant. The optimal shot, with a 4:1 mass ratio, produced a shorter (4.5 ns) x-ray pulse, compared to the case with a single array (7 ns), resulting in an increase in x-ray power. These nested arrays provide the potential to produce even higher temperature hohlraums. The pulse shortening is consistent with pre-shot simulations with the 2D MHD code MACH2 that, along with LANL's 2D MHD simulations, will continue to provide guidance for future shots. Experiments to confirm and quantify the higher x-ray power for nested arrays with four complementary sets of soft x-ray diagnostics are scheduled for December.

An intriguing aspect of wire-array z pinches is the strong dependence of radiation pulse width on wire number. An analytic model suggests why, as the number of wires is increased, instabilities decrease. The instability growth rate is $\gamma = \gamma_K / (1 + \lambda/g)^2 + \gamma_{RT}$, where γ_K is the kink instability growth rate, $(1 + \lambda/g)^2$ is a geometric factor dependent on the instability wavelength λ and the interwire gap g, and γ_{RT} is the Rayleigh-Taylor growth rate. The kink instability dominates at low wire number and the Rayleigh-Taylor instability at high wire number. The model shows the observed leveling off of the radiated pulse width for small gaps and the rapid increase in pulse width for large gaps.

Two x-ray sources unrelated to the soft x rays generated at peak compression of the z-pinch plasma are present on Z, as seen in film images from a bremsstrahlung pinhole camera (lower left figure) and in the photon spectrum from a thermoluminescent detector stack placed above the anode. These sources are bremsstrahlung from electron loss in the vacuum feeds and from electrons accelerated vertically in or near the pinch toward the anode. Electrons from feed losses have energies of < 2 MeV, and electrons accelerated in the vicinity of the pinch can have energies > 5 MeV. Preliminary data suggest that the bremsstrahlung time dependence must be taken into account to obtain precision equation-of-state data for stockpile stewardship. Efforts are underway to understand how this bremsstrahlung is created and affects interpretation of diagnostic data. We are developing time- and space-resolved diagnostics and performing electron-photon transport calculations that tally the bremsstrahlung as a function of energy and angle.